



**Fermi National Accelerator Laboratory**

**FERMILAB-Conf-91/276-E**

# **The Lepton Asymmetry in W Production and Decay at CDF**

**B. Winer**

*University of Rochester*

**for the CDF Collaboration**

*Fermi National Accelerator Laboratory  
P.O. Box 500, Batavia, Illinois 60510*

**October 1991**

\* Presented at the *Joint International Lepton-Photon Symposium and Europhysics Conference on High Energy Physics*, Geneva, Switzerland, July 25-August 1, 1991.



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Brian L. Winer, University of Rochester  
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### ABSTRACT

The CDF detector was used to measure the asymmetry,  $A(Y_l)$ , of leptons from the decay of W bosons produced in  $p\bar{p}$  collisions at  $\sqrt{s} = 1.8$ . The W bosons were identified by the existence of an electron or muon with large transverse energy along with a large amount of missing transverse energy in the event. The observed asymmetry is the convolution of the W production asymmetry and the decay asymmetry. The production asymmetry is dependent on the d/u ratio in the proton and therefore dependent on the structure functions. The measured asymmetry is compared to predictions from various structure functions.

In  $p\bar{p}$  collisions at the Tevatron, 85% of the W bosons produced are valence-valence or valence-sea interactions of a quark and antiquark. Therefore, typically  $W^+$  bosons are produced with a  $\bar{d}$  quark from the antiproton and a u quark from the proton. Because the u quark has, on average, larger momentum than the  $\bar{d}$  quark, the  $W^+$  is produced more often with momentum in the proton direction (positive rapidity (Y)). This causes an asymmetry in  $d\sigma(W^+)/dY_w$ . The size of the asymmetry is dependent on the difference between the u and d quark momentum distributions and therefore the structure functions. The W production asymmetry can be related to a function of the d/u ratio [1]. Therefore, if the W asymmetry could be measured, it would provide information about the proton d/u ratio at a very high  $Q^2$  ( $= M_W^2$ ).

Unfortunately, the W asymmetry can not be directly measured at the Tevatron because W's are tagged by their leptonic decay and the longitudinal momentum ( $P_z$ ) of the neutrino (and therefore the W  $P_z$ ) is not measured. However, the asymmetry of  $d\sigma/dY_l$  for the charged lepton can be measured. The asymmetry is defined as,

$$A(Y_l) = \frac{d\sigma(+)/dY_l - d\sigma(-)/dY_l}{d\sigma(+)/dY_l + d\sigma(-)/dY_l} \quad (1)$$

where  $Y_l$  is the rapidity of the charged lepton and  $\sigma(+)$  ( $\sigma(-)$ ) is the cross section for a  $W^+$  at  $+Y_l$  ( $-Y_l$ ). The  $W^-$  events can be added with a change of sign. This asymmetry is a convolution of the W production asymmetry and the decay asymmetry. The leptonic decay has a  $(1 \pm \cos\theta)^2$

distribution from the V-A coupling at the decay vertex. The magnitude of the leptonic decay asymmetry is dependent on the kinematic cuts imposed on the charge lepton and the neutrino. By cutting hard on these quantities, it is possible to reduce the effect of the leptonic decay asymmetry and make  $A(Y_l)$  a closer approximation of  $A(Y_w)$ .

The charged lepton asymmetry was measured using the CDF detector [2]. The data was collected during the 1988-89 Tevatron run and corresponds to approximately  $4.3 \text{ pb}^{-1}$  of integrated luminosity. The W boson events were selected by searching for events containing an electron or muon with large transverse energy ( $E_T$ ) and a large amount of missing transverse energy (MET) [3]. The electron was required to enter the calorimeter either in the central ( $|Y_l| \leq 1.0$ ) or the plug ( $1.1 \leq Y_l \leq 2.4$ ) fiducial region. The muon was required to be in the central ( $|Y_l| \leq 0.6$ ) muon fiducial region. For central electrons or muons, the  $E_T$  of the charged lepton and the MET are required to be greater than 20 GeV. The transverse mass of the lepton-MET combination was required to be greater than  $50 \text{ GeV}/c^2$ . For plug electrons, the  $E_T$  cuts were both 25 GeV and the transverse mass cut was  $60 \text{ GeV}/c^2$ . For both electrons and muons, quality cuts were made in order to separate real leptons from objects faking a lepton signal [4,5]. Using Monte Carlo and cosmic rays, these selection criteria were determined to be charge independent to better than 1%. Finally, W events with energy

clusters (other than the lepton) with  $E_T \geq 10$  GeV were eliminated to reduce the effect of higher order QCD correction to the leading order predictions. The final sample consists of 1605 central electron events, 800 central muon events, and 262 plug electron events. The remaining background is approximately 1% for the central electrons and muons and approximately 2.5% for plug electrons.

The  $A(Y_l)$  was calculated by combining the positively charged leptons at positive rapidity with the negatively charged leptons at negative rapidity. The calculated asymmetry is shown in Figure 1. The figure shows the measured asymmetry for the three subsets and the combine data set. The lines give the predictions from various choices of structure functions. The larger asymmetry in the plug region is due to the higher transverse mass cut. Many of the data points show a larger asymmetry than the predictions; however, the uncertainty of each value is large and the measured asymmetry is consistent with all the predictions [5]. The Tevatron will provide an integrated luminosity of 50 to 100  $\text{pb}^{-1}$  over the next several years. This will allow a three fold reduction of the statistical uncertainty which is the dominate source of error.

This work was supported by the United States Department of Energy, the NSF, the Istituto Nazionale di Fisica Nucleare, the Ministry of Science, Culture and Education of Japan, and the A. P. Sloan Foundation.

## References

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- [2] For a detailed description of the CDF detector: F. Abe *et al.*, *Nucl. Instrum. Methods Phys. Res., Sect. A* **271**: 387 (1988).
- [3] The missing transverse energy is calculated from the imbalance of the transverse energy deposits in the calorimeter. This imbalance is interpreted as the transverse energy taken by the neutrino which escapes detection.
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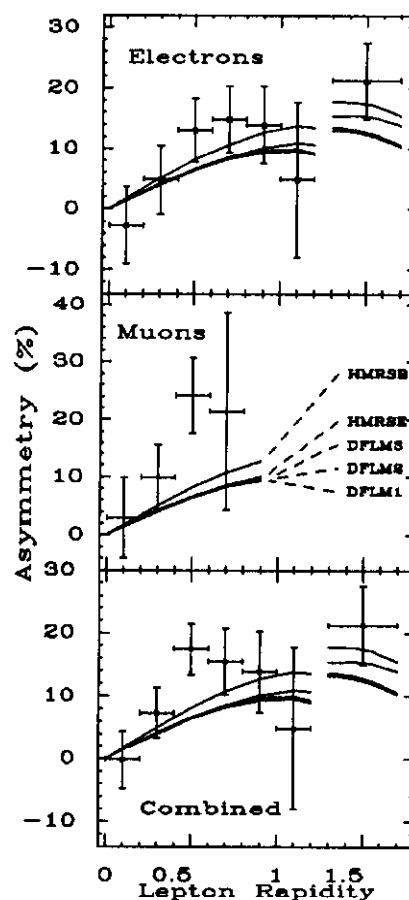


Figure 1: The lepton asymmetry,  $A(Y_l)$ , in W boson events: (Top) central and plug electrons, (Middle) central muons, (Bottom) combined electron and muon data sets.